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INFORMATION FROM "FLAMELESS SURFACE COMBUSTION" BY M. B. RAVICH

The following report presents information on flameless surface combustion from the above book by Professor M. B. Ravich, Doctor of Technical Sciences. It includes the Foreword in full, a condensation of the Introduction, excerpts from the body of the book, and the Table of Contents in full.

FOREWORD

Academician A. V. Vinter

Natural gas is being extensively utilized in industrial enterprises and municipal utilities of Saratov, Kuybyshev, L'vov, and other cities of the USSR. Gas has already become an important fuel in a number of sections of the country. In the next few years its importance will increase. In 1948 the Dashave--Kiev and the Kokhtla-Yarve--Leningrad gas pipelines were opened. While Kiev receives cheap natural gas from the Carpathian area, Leningrad is supplied with combustible slate gas from Estonia. In addition to gas produced at Moscow plants and natural gas coming from Saratov, in 1949 Moscow will receive coke-oven gas from the coke-gas combine which is now under construction. Other types of gas fuel will also be supplied to Moscow.

Under the circumstances, problems connected with the conversion of boilers and furnaces to the utilization of this new type of fuel are acquiring a great economic importance. Supplying the industry and the municipal economy with gas must be accompanied by a reduction of the relative expenditure of fuel and a more efficient operation of heat equipment, so that capacity will be increased without extra capital investment. In a number of cases the application of methods of flameless surface combustion will be particularly effective, because these methods permit combustion of the gas under such conditions that a high rate of heat output results with a minimum excess of air, and because specially designed new equipment of a smaller and more economical type can be introduced.

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This volume reports results of work in the field of flameless surface combustion which are based on investigations carried out at the Laboratory of Fuel and Combustion of the Power Engineering Institute imeni Academician G. M. Krzhizhanovskiy, Academy of Sciences USSR, under the direction of the author. Results obtained at other institutes and at industrial enterprises have also been included.

The problem of surface combustion was studied at the Power Engineering Institute of the Academy of Sciences from every angle. In the course of the work done there, the effect of catalysts on the process of combustion was investigated; flameless combustion was combined with high-temperature preheating of air; new boilers distinguished in their construction by the use of a very low quantity of metal and a very high degree of efficiency were designed; the multipurpose utilization of heat produced by gas in a special type of equipment designed for flameless surface combustion, and named boiler-furnace, was studied; and the use of the pure combustion products as inert gas or carbon dioxide fertilizer was investigated.

On the basis of this work, erroneous opinions held by many foreign scientists were refuted. These included Aufgeiser's view that it is impossible to carry out flameless combustion of heavy hydrocarbons; Rummel's view that the efficiency of gas combustion is determined only by the degree of mixing with air; Davis' view that only platinum may catalyze combustion; Fukuda's view that catalysts do not accelerate the process of combustion, but only lower the temperature of combustion; and W. Bone's view that methane reacts much more energetically with oxygen than the latter reacts with hydrogen; also, the opinion that at high temperatures differences in the catalytic action of incandescent surfaces of solid substances disappear, etc.

This is the third edition of Professor M. B. Ravich's work. It includes new data on the flameless combustion of natural and diluted gases, on "furnaceless" boilers for heating water, multistage utilization of gas for the production of hot water and the heating of low-temperature furnaces, application of methods of flameless gas combustion in connection with heat recovery by means of high-temperature air preheating the catalytic gasification of solid fuels, etc.

Four thousand copies of this edition have been published.

INTRODUCTION

The process of combustion has been studied extensively in the USSR. The theory of chain reactions which has been developed by Academician N. N. Semenov led to a clarification of the reaction mechanisms of the combustion of hydrogen, carbon monoxide, and hydrocarbons. At the Institute of Chemical Physics, Academy of Sciences USSR, Corresponding Member Ya. B. Zel'dovich, Corresponding Member V. N. Kondrat'yev, and Professors D. A. Frank-Kamenetskiy, A. S. Sokolik, and M. B. Neyman have done work which considerably advanced the theory of the combustion of fuels.

Extensive investigations on the combustion of solid fuel have been conducted by Corresponding Member A. S. Predvoditelev and his school -- Professors L. N. Khitrin and V. I. Blinov, O. A. Tsukhanova, and others in Moscow, and Professor G. F. Knorre and his collaborators in Leningrad. These investigations are of pre-eminent significance for a correct understanding of the process of combustion of solid fuel.

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In connection with the construction of the Saratov--Moscow, Dashave--Kiev, and Kokhtla-Yarve--Leningrad gas pipelines, the erection of coke-chemical plants, and the advancement of the gasification of solid fuels, perfected methods for the combustion of gas, such as the method of flameless surface combustion, assume particular importance.

Gas can be utilized in a more efficient and more convenient manner than any other type of fuel. One of its advantages is that very pure combustion products are obtained. However, when gas is burned by a process which has not been properly planned and devised, the results can be rather unsatisfactory. It is regrettable that advantageous conditions for the efficient utilization of expensive gas fuel, particularly of natural gas, are often not being applied. Under these circumstances, a lower efficiency of furnaces may result than that obtained when some other type of fuel is used with which the personnel is more familiar, as far as the technique of its combustion is concerned.

The present work indicates several new possibilities of utilizing in technology one of the most efficient methods of combustion, flameless surface combustion. This method has been widely applied in the combustion of gas fuel, and is also of undoubted interest in the combustion of liquid and solid fuel.

Investigations at the Laboratory of Fuel and Combustion (directed by the author) of the Power Engineering Institute imeni Academician G. M. Krzhizhanovskiy were pursued along the following lines:

1. The influence exerted on the process of combustion by solid surfaces at various temperatures was studied, and the effect of different refractories was compared in that respect. Chemical activation of refractories was carried out, and the catalytic properties of naturally occurring refractories were established.

2. Methods of surface combustion as applied to various types of gaseous, liquid, and solid fuel were investigated.

3. Effective ways of applying flameless surface combustion in various technical fields, and of utilizing the heat supplied completely by gas in multistage processes were developed.

4. The possibility of using the pure smoke gases obtained in flameless surface combination was investigated, and the efficiency of this type of processes was considered.

The application of results obtained in these investigations has led in many cases to savings of fuel and to improvements in the technological processes involved.

EXCERPTS

Flameless combustion is not yet being applied abroad for the heating boilers producing steam or hot water, because experimental installations erected on the basis of W. Bone's work on fire-tube furnaces in England and that of R. Schnabel's work, and the Bamag Company's designs in Germany were largely unsuccessful. Successful steam-generating and hot-water boilers which operate under application of flameless surface combustion were first constructed in the USSR. The Power-Engineering Institute of the Academy of Sciences USSR and VNIIT (All-Union Scientific Research Institute of Fuel Utilization), formerly the Ural Branch of the All-Union Heat Technology Institute, are responsible for the development of this type of equipment.

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As distinguished from the work done abroad, Soviet engineers who were active in the field of flameless combustion concentrated on the construction and conversion of water-tube rather than fire-tube boilers. In the course of his work on the subject, Bone was concerned only with the heat resistance of refractories and completely disregarded their catalytic effect. The catalytic activation of refractories used in flameless burners was first carried out in the USSR. /pp 12-14 and 153/

Extensive work has been done by Professors V. A. Ushakov and N. M. Karavayev on the conversion of forge furnaces to gas burned by the method of flameless surface combustion. The following plants were equipped with furnaces of this type, using tunnel burners: Rostsel'mash (Rostov Agricultural Machine-Building Plant), Freyzer (Milling Machine Plant) imeni M. I. Kalinin, Uralmash (Ural Machine-Building Plant), Dnyeprodzerzhinsk Plant imeni F. E. Dzerzhinskiy, Izhevsk Plant, etc. Furnaces with tunnel-type flameless burners are being designed by Stal'proyekt (State Steel Plant Equipment Engineering Design Office), Soyuzteplostry (Construction of Heating and Furnace Installations Trust), and other organizations. During recent years, many Soviet machine-building plants were equipped with heat-treatment furnaces of the flameless surface combustion type. Flameless tunnel burners are also being applied in the heating of boilers producing steam or hot water.

Tunnel burners are simply refractory lined channels which pierce the wall of the furnace and serve as inlets for the gas-air mixture. Because partial combustion takes place in the refractory walls of the tunnels, the latter are shaped in such a manner that the heat is reflected from them to the point of application. /pp 13-14/

Engineer A. V. Arseyev of VNIIT has successfully converted to flameless heating many steam boilers operating on blast-furnace gas in the Urals and the Donets Basin. His design involves the use of burners equipped with refractory caps or nozzles. /p 158/

In the field of petroleum technology, a considerable saving of space and improvement in efficiency can be achieved by constructing pipe stills which operate on the principle of flameless combustion. Experimental pipe stills of this type, in which oxidative cracking is carried out, have been constructed in the course of work done at the Power Engineering Institute by M. B. Ravich and V. A. Speysher, and at the Institute of Fossil Combustibles, Academy of Sciences USSR, by K. K. Dubravay, A. B. Sheyman, V. Ye. Glushnev, and S. F. Vasil'yev. The fuel used in this type of installation is obtained by carburizing gasoline or liquid by-products of synthetic rubber production.

The results obtained by operating such an installation in 1942 showed that the temperatures in the evaporation zone (400°) and in the reaction zone (700°) could be regulated with a great degree of precision, which is a prerequisite for carrying out industrial pyrolysis under optimal conditions. Furthermore, the efficiency was 500,000 cal/cu m/hr, which exceeds by a factor of 10 the efficiency of ordinary industrial pipe stills. With the use of the new method, coking in the pipes was absent, and the danger of local over heating was therefore eliminated. Heat losses, which were already low due to the small size of the equipment, could be reduced still further, because it was possible to operate with almost no excess of air. /pp 210-212/

"Khemiko" evaporators burning mazut and constructed so that the products of combustion are bubbled through the solution to be evaporated (for instance, sulfuric acid) were successfully converted by M. B. Ravich and V. A. Speysher to operation on illuminating gas or wood-generator gas having a low calorific value under utilization of the principle of flameless combustion. /pp 229-35/

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Flameless burners for evaporation which heat directly the surface of the liquid from a distance of 40 mm have been constructed and found satisfactory in operation. [p 83]

By applying flameless surface combustion, dilute gases having a low calorific value can be utilized to advantage. This applies to gases obtained by underground gasification of coal, cupola-furnace gas, and to the gas resulting in the hot-blowing stage of the water gas process. Although the latter contains up to 15% of carbon monoxide, together with some hydrogen, and has a temperature reaching 800°, many chemical plants let it go to waste. These plants include the Bereznikov Combine imeni Voroshilov, the Chernorechensk Chemical Plant imeni Kalinin, and the Moscow, Leningrad, Gor'kiy, Kazan', Novosibirsk, Evdakovsk, and other hydrogenation plants of the Ministry of Food Industry USSR. To hydrogenate one ton of oil, these plants develop 80 cu m of hydrogen. This requires 160-200 cu m of water gas, and to produce the latter, 300-400 cu m of gas from the hot-blowing stage are let to waste. Electric lamp factories which operate on water gas also waste their hot-blowing gas.

In the combustion of gas having a low calorific value, the use of dunite or chromite is advantageous. The active refractory material, a refractory cap or nozzle, should almost completely fill the combustion chamber to insure complete oxidation of the carbon monoxide at 400°, rendering the final waste gas harmless.

Measures of this type may also prove useful in the final combustion of waste gases other than hot-blowing or cupola-furnace gas, as, for instance, waste gas resulting from the production of carbon black from petroleum products or natural gas. The composition of the dry waste gas of carbon black plants is 5-8% CO_2, 1-2% O_2, 3-4% CO, 9-12% H_2, and 75-76% N_2. This gas contains approximately 50% water vapor.

The combustion of waste gases in furnaces of the ENIN-2 type, which are equipped with catalytically active refractory nozzles, insures safe and complete combustion. These furnaces are designed so that the heat derived from the condensation of water vapor contained in combustion products is also utilized. By using flameless surface combustion, the danger of explosion is eliminated in the case of both hydrogen-oxygen and carbon monoxide-oxygen mixtures. [pp 251-7]

Experimental work on the final combustion of exhaust gases of internal-combustion engines with the aid of activated refractory nozzles (chamotte plus nickel or iron oxides, or chamotte plus 10% iron oxide plus 1% manganese oxide) was carried out at the Power Engineering Institute in 1947.

A series of investigations on the flameless surface combustion of heavy liquid fuels, particularly mazut, was completed at the Power Engineering Institute. During these investigation, the possibility of utilizing coal dispersed in mazut in the process of flameless combustion was also tested. This fuel was found to be entirely satisfactory for this purpose.

L. Ya. Margolis completed an interesting investigation on the catalytic combustion of hydrocarbons at the Laboratory of Catalysis, Institute of Physical Chemistry, Academy of Sciences USSR. During this investigation, the high catalytic activity of copper aluminate, magnesium chromite, and iron chromite was established with reference to hydrocarbon oxidation when a stream of isooctane was blown with a velocity of 0.5-5 cm/sec. [pp 257-66]

As shown in the example of the German ME-163 jet plane, which was propelled by a mixture of concentrated hydrogen peroxide and methyl alcohol with potassium permanganate added to expidite combustion, a liquid fuel can be activated by the addition of a catalyst. In this connection, the catalytic activation of the walls of combustion chambers and of ignition appliances is also of considerable interest. [pp 267]

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Flameless coal briquettes have been developed, tested, and produced in the USSR. The crude material for the production of these briquettes is charcoal, peat coke, or coal coke fines. They are activated by the addition of 3-4% of wood ash or 2% of sodium carbonate or sodium chloride. Pitch from peat coking as a binder and a considerable quantity (20%) of coal-tar sediment are used in the production of these briquettes. An interesting application of flameless briquettes is their burning in special boxes to facilitate the starting of automobiles in cold weather. /pp 277-81/

Flameless surface combustion of gas is so efficient that one must seriously consider the replacement of some electric furnaces with furnaces using gas. This will be of particular advantage in the case of natural gas because any investment in connection with the construction of gas generator installations is unnecessary there. The replacement of electric power with natural gas would be a matter of great importance in Moscow, Kiev, L'vov, Saratov, Baku, and other cities where electric power plants partially utilize natural gas as a fuel. The efficiency factor of steam power plants, including those operating on natural gas, does not exceed 25%. Thus, 75% of the potential energy of gas fuel are lost in plants of this type. Consequently, it would be expedient to use gas instead of electric power in furnaces for melting aluminum, magnesium, and aluminum and magnesium alloys; also, in process furnaces, muffle furnaces of various types, hardening baths, driers, etc. If this is done in areas where natural gas is available, the output of large electric power stations will be available to other consumers. One should note in this connection that the application of gas by the method of flameless surface combustion in the melting of magnesium alloys is not only more economical, but safer than melting with the use of electric power. /pp 227-8/

Many low-temperature technological processes are carried out by means of utilization of gas burned with a large excess of air. If the quantity of air is reduced /by using an efficient process like flameless surface combustion/, the amount of heat lost in waste gases will be reduced, too, and by-product heat at a higher temperature will be available for the heating of water and generation of steam. Central heat generation in cities is being applied extensively in the USSR by means of utilization of low-temperature heat available at electric power plants. Under the scheme suggested above, the light industry, enterprises of the food industry, and other industrial establishments will be in a position to supply additional heat for the production of hot water used in dwellings. Multistage utilization of high-pressure steam generated in flameless combustion boilers (i.e., use of steam coming from the turbine-generator stage for the heating of water or some other purpose) by means of gas as a fuel would be still more efficient. /pp 228-9/

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